Biogas Energy

Unleashing the potential for productive appliances in farming

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Introduction

Globally there are an estimated 570 million smallholder and family farms, home to over 2 billion people who manage 75% of all agricultural land and produce the majority of the world's food.[1] Approximately half of these farms have enough organic waste feedstock to power a Sistema.bio anaerobic digester (>2 cows equivalent) to produce energy and fertilizer. Smallholder farmers are among some of the most disadvantaged in the developing world, without access to

[1] FAO, 2106 https://doi.org/10.1016/j.worlddev.2015.10.041

technology, training and financing to improve their productivity. Using animal manure to produce biogas has the potential to reduce manure related emissions by capturing the biogas for clean cooking and energy for productive use, at the same time indirectly reducing deforestation and local environmental degradation.

Sistema.bio has traditionally offered a range of thermal cooking appliances to serve household energy needs and limited agricultural processing with industrial burners.

With Shell Foundation (UK Registered Charity) and DFID's support, Sistema.bio explored how to also serve the needs of larger family farmers by offering biogas appliances to meet the productive energy needs of these farms. Through this partnership, research was conducted with 5,000 farmers based across Mexico, India and Kenya to answer the question: ***How does productive use biogas appliance innovation contribute to increased energy access, to rural livelihoods and to the development of biogas as a utility?***

This report provides an insight into how Sistema.bio approached these questions through existing marketing and sales teams, while also leveraging over 7,000 existing clients, to understand how biogas appliances can drive improved sales results for our teams around the world.

Figure 1: African Family cooking with biogas. Cook stoves are the most popular biogas appliances.

This learning report shows a broad biogas portfolio of products for thermal and mechanical usages.

About Sistema.bio

Sistema.bio offers high quality anaerobic digestion technology to covert animal manure into clean renewable fuel—biogas—that can provide clean energy and fertilizer to support the productivity, efficiency and sustainability of smallholder farmers in developing agricultural markets around the world. Founded in 2010 in Mexico, and now with over 7,000 units installed with costs as low as $400 per unit, we have delivered the benefits of biogas to more than 45,000 users worldwide.

Key benefits to biogas energy for farmers

There are significant benefits to farmers that are able to integrate household and larger biogas systems.[2] Farmers can mechanize their processes, ensure stable electricity supply, and create significant economic savings by creating their own energy. This report focuses on the benefits of biogas appliances for productive energy use. However, it should be taken into consideration when analyzing the overall impacts, market demand and quality of the investment for the farmer that there are other significant benefits to the development of larger scale biogas plants. First, anaerobic digesters provide important waste treatment and handling services that reduce contamination, insects and odors that impact public health and their relationships with surrounding populations. Second, the biofertilizer production provides important opportunities to recycle nutrients, improve their soil quality and increase agricultural output. Finally, there are significant greenhouse gas emissions reductions, decreased water contamination and reduced stress on local forests and resources.

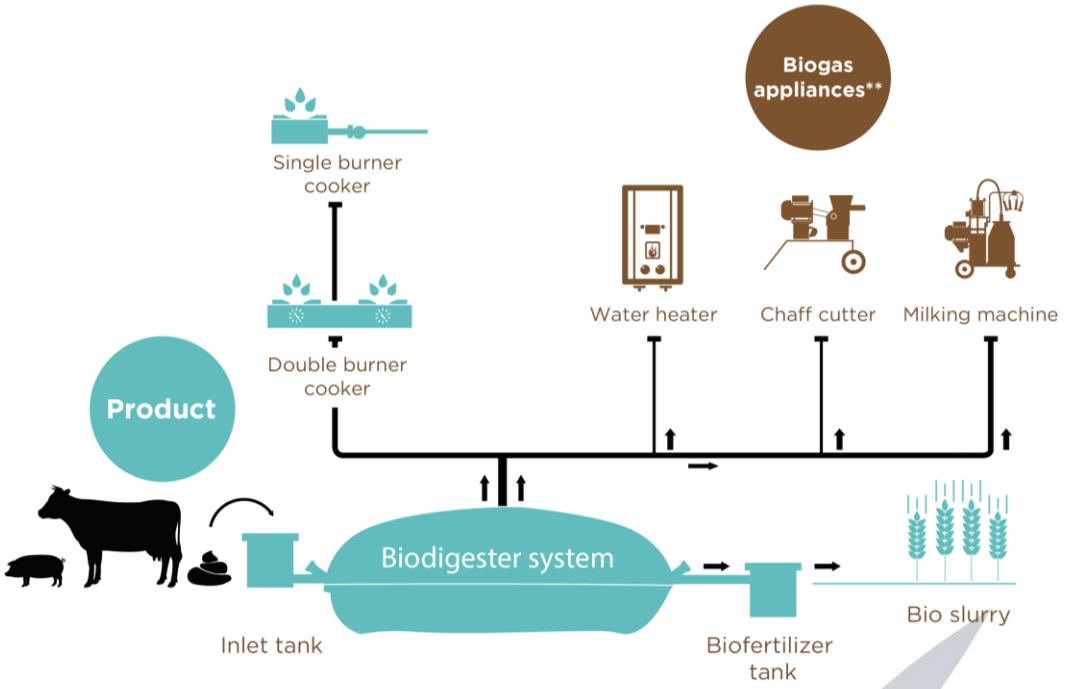

Figure 2 : Thermal and mechanical usages with Sistema.bio digesters

[2] WORLD BANK GROUP, 2019 http://documents.worldbank.org/curated/en/468451557843529960/pdf/The-Power-of-Dung-Lessons-Learned-from-On-Farm-Biodigester-Programs-in-Africa.pdf

The opportunity to increase access to energy, especially for productive uses, is significant with biogas. Biogas energy is easy to store and is dispatchable at all times. This allows systems to easily adjust to the needs of farmers and compliment other energy systems. In addition, it is more cost effective to provide higher capacity power systems to provide the productive thermal, mechanical and electrical demands that farmers have. Where energy access is already established through either diesel engines or grid electricity, biogas provides an economically viable alternative, provides important redundancy and back-up power and delivers a low-carbon energy alternative.

Energy has been shown to increase agricultural productivity by saving farmers time, improving the quality of agricultural products, extending the cold chain and improving overall efficiency of processing. This directly impacts regional and global food security, with over 70% of the food production in developing countries coming from smallholder farmers. Investing in agricultural productivity, in turn, has been shown to be the most effective intervention against rural poverty. In addition, biogas energy provides a clean, carbon negative, regenerative energy source to displace greenhouse gas emissions, dangerous health conditions, and environmental degradation.

The focus of this research is anticipating customer demand for productive biogas appliances through customer insights and market studies. This will support our original research question:

How does productive use biogas appliance innovation contribute to increased energy access, to rural livelihoods and to the development of biogas as a utility?

To begin answering these questions we focused initially on three areas of research:

Understanding the potential to increase demand of productive farmers for large biogas systems by increasing the availability of larger scale biogas appliances outside of cooking fuel; understanding the potential to sell additional biogas appliances to our existing clients after they have paid off the basic cooking system, and; creating a clear economic model to understand the benefits to increasing energy access and reducing energy costs on farmer livelihoods.

Methodology

We collected data from our existing clients and additional farmers that fit out customer profile for productive scale: more than 20 cows, more than 5 acres and energy demands beyond domestic household cooking needs. We asked farmers to define their energy costs and assign their energy costs different energy uses. We approached farmers at markets, agricultural fairs, cooperative meetings and sometimes directly in their farms. These customer insights were collected in Mexico, Kenya and India in 2018.

We also reviewed data from over 5,000 existing clients to see how many could use productive energy use on their farms today. We asked a subset of these farmers what other biogas appliances and products they would be interested in purchasing from Sistema.bio.

Data was captured in the Sistema.bio online data collection platform (Taro Works, with a Sales Force interface), on paper surveys or through sales team interviews. The data was compiled into a simple table to outline the potential for increased follow-on sales to existing clients and to sell more digester systems to people that want more advanced biogas uses. This data was then used to set development priorities of new products.

Reviewing the agricultural markets where we work, we defined the proportion of farms that have access to grid electricity, and then reviewed estimates of electricity availability as a proportion of the day to understand reliability. Farmers require reliability for many of their agricultural activities, including milking, pumping water, milling and chilling. We also documented a range of energy costs from energy alternatives in the same markets. This includes the range of grid-supplied electricity prices to farmers and the cost of generating mechanical and electrical power with diesel powered engines. We also calculated the economic impacts of increasing energy access at farms as an alternative to grid electricity and diesel fuel powered appliances.

Results

Customer Demand

First, we reviewed a large sample of our existing farmers to understand which farmers had either existing productive scale equipment or the need for productive energy services. The table below shows the percentage of farmers that have or want productive scale agricultural energy consumption in their farms. This table show that in Mexico, where we started without a vision for larger farms (and without productive biogas appliances) our portfolio of customers tends to have less advanced energy consumption. However, in Kenya and India a larger percentage of our existing farmers could use productive scale energy devices today.

Table 1 Percentage of Sistema.bio clients with productive energy needs.

	Sample Size Number of farms	Productive Energy Uses Number of farms	%
LATAM	3372	74	2 %
KENYA	1620	522	32%
INDIA	88	41	47%

We further explored the demand for productive agricultural energy appliances of over 400 farmers. The demand of all the farmers was mechanical or electrical, split between three broad categories (specific equipment size, type and brands varied).

Table 2: Most demanded agricultural appliances

Water Pumps	197	49%
Milking machine	101	25%
Chaff Cutter/ Milking Machine	108	27%
Total	**406**	**100%**

In India, we took the additional step of setting up surveys at agricultural events where we would qualify participants as productive farmers, make a short pitch for productive biogas systems with appliances, and gage their interest. The 13% response rate was very encouraging, similar to our global rates in more established markets.

Table 3: Results of surveys Indian agricultural events measuring potential customer interest in productive systems and appliances.

Total Productive Farmers Contacted	Total Expressed Interested	Interest %
3122	408	13%

From this sample of Indian productive scale farmers, we created a focus group of 48 large farmers where we collected more specific data. We saw that there was an average USD$150 / mo. in household energy expenses, but between USD$1500 – 2000 / mo. in productive energy expenditures, mostly in diesel fuel. The driver of these costs is intermittent electrical grid power supply, forcing farmers to use back up energy generation in the form of diesel generators at over three times the cost of energy from the national electrical grid.

The Sistema.bio India, Kenya and Mexican sales teams also contributed data from their sales experience where they found an overwhelming demand for productive electrical, mechanical and thermal appliances when pitching to productive scale farmers. Hot water heaters and boilers to provide hot water for domestic and commercial uses were excluded from our original survey questions as the focus was “advanced” technology considering mechanical and electrical demands. Heating water is a significant energy demand in many rural households and farms, especially where there are colder average temperatures. Specifically, larger dairy farmers need to heat a lot of water (minimum of over 100 liters over 80 degrees C) to clean milking equipment to meet minimum quality standards for milk sales.

In Mexico, over 10% of the households have installed boilers for domestic hot water heating, and in Kenya (where there was initially a photo of a boiler in our catalogue), there was a waiting list of 232 farmers (over 13% of clients) that had registered to purchase a boiler for the home or farm.

In addition to the productive use biogas appliances, our surveys and questions to farmers revealed that there was great interest in water tanks, silage storage, irrigation systems and biofertilizer management equipment (pumps, mixers, and sprayers). These items came up in many interviews with existing clients and other farmers and will be considered separately

Figure 3: Kenyan farmer using Sistema.bio water heater for productive usage.

Energy Access and Energy Costs

When first looking at the access to grid supplied electrical energy, we found coverage in the markets that we serve was over 72% in Kenya, nearly 90% in India and reported at 98% in Mexico. However, the reliability of this energy is relatively low, with high proportional down time during a single day in India, with agricultural supplies for only 1-3 hours per day. In Kenya there were a significant amount of days without power, averaging over 30% downtime in some areas. In Mexico we found significant gaps in reliability and connections for agricultural operations. We also compared the range of electricity costs to the farmers in each market, as shown in the table below. It is important to note that this electricity is subsidized by the government in each of these markets, so prices do not reflect the grid production cost, nor the carbon intensity of the electricity delivered. This should be considered when informing energy development decisions at national and international levels.

Table 4 : Electrical rates per country

		India		Kenya	
Cost	**unit**	**INR**	**USD**	**KES**	**USD**
Average grid tied electrical rates for commercial farms	KWh	12.00	0.17	20.50	0.21

Where the electrical grid is not available, diesel fuel or gasoline are the most likely alternative to run productive scale energy needs. The cost of running both diesel and gasoline powered engines where considered for each market. Here, diesel costs are also largely controlled and subsidized, without GHG emissions considerations.

Table 5: Electrical production cost by fuel and country

		India		Kenya	
Cost	**unit**	**INR**	**USD**	**KES**	**USD**
Electrical Production Cost with Diesel	KWh	24.00	0.34	42.00	0.42
Electrical Production Rates with Gasoline	KWh	29.00	0.41	48.00	0.48
Electrical Production with Duel Fuel Biogas / Diesel	kWh	7.20	0.10	12.60	0.12

Finally, the costs of running thermal appliances on LP Gas was considered in each market to generate a comparison to LP Gas alternatives that could be used to run thermal agricultural equipment like pasteurizers, cheese makers, and water heaters for cleaning equipment and agricultural products. Here, LP Gas also has significant subsidies.

Table 6: Cost of LP Gas (Kg) by country

		India		Kenya	
Cost	**Unit**	**INR**	**USD**	**KES**	**USD**
LP Gas	KG	32.00	$ 0.46	59.00	$ 0.59

Sistema.bio has a developed a range of energy production alternatives that can provide energy access where there is none and can also displace existing energy sources. The benefits of displacing each fuel is shown in the table below as compared to different capacities and overall hours.

Table 7: Economic Savings over Equipment Lifetime

				India		Kenya	
Type	**Baseline Cost Comparion**	**Capacity (kW)**	**Hours**	**INR**	**USD**	**KES**	**USD**
100% Biogas	Grid Electricity	3	10000	$ 360,000.00	$ 5,142.86	$ 123,000.00	$ 1,230.00
	Diesel Elecricty	3	10000	$ 720,000.00	$ 10,285.71	$ 252,000.00	$ 2,520.00
70% Biogas	Grid Electricity	3	10000	$ 144,000.00	$ 2,057.14	$ 47,400.00	$ 474.00
	Diesel Electricty	3	10000	$ 504,000.00	$ 7,200.00	$ 176,400.00	$ 1,764.00

Discussion

What is the demand for productive use biogas appliances?

In order to create demand for larger Sistema.bio anaerobic digestion equipment, there is a clear need to offer productive use biogas appliances to drive that demand. Sales agents in Kenya estimate that they would be able to sell an additional 35% or more with such items on a unit basis, which would increase margins and overall revenue.

Biogas cookstove

In India and Kenya, there is an opportunity to offer 47% and 32% of our existing clients, respectively, an additional productive use biogas appliance. Here, these farmers would be able to offset existing costs with biogas. In Mexico where the number of farmers with productive energy uses is lower, there is an opportunity to increase our mix of larger farmers and potentially introduce appliances to farmers that may need them but have not made the investment.

Thermal appliances, such as boilers for domestic hot water, seem to have consistent appeal as well. There were scenarios in which additional thermal appliances can have very high payback when offsetting commercial LP Gas, or where food processing and value add services could be added to agricultural systems.

Industrial biogas burner

How does productive use biogas appliances improve livelihoods?

Productive scale farmers spend more money on productive scale energy uses than on domestic uses. In India, this increase was over 10X. This suggests that productive scale energy devices will drastically increase the return on investment for farmers.

When dealing with productive farmers, it appears that providing biogas appliances that support water pumping, milking and chaff cutting or grain processing will cover the vast majority of the farms' productive energy consumption. This creates significant economic

Industrial biogas burner

benefits for famers over the long term, providing a clear economic rationale for investing in biogas infrastructure.

Adapted biogas engine

How does productive use biogas appliance contribute to the development of a utility?

The economic and technical feasibility of providing biogas appliances to larger farmers shows the potential to utilize biogas to produce electricity for milling, pumping and other productive services opens up the door to consider biogas as a utility for the broader community. These types of services can be run for community benefit and also as an additional business opportunities for smallholder farmers. Additional work to support these appliances, such as biogas pumping, filtration and storage has also improved the viability to distribute biogas in piped grids for cooking fuel and for running these appliances. This opens many energy development avenues in rural communities which are in process of pilots, research and demonstration currently.

Adapted biogas Wáter pump

Conclusions

Our data shows that the addition of productive scale biogas appliances can increase energy access, specifically productive energy access, for small farmers that do not have mechanical energy or that underuse mechanical energy because of energy costs and electricity reliability. The data shows that we can improve livelihoods for hundreds of millions of households by adding value in the agricultural value chain through thermal and mechanical energy, and also by creating significant energy savings at productive scale farms.

We have concluded from this data that the introduction of mechanical energy biogas appliances that can run pumping, milling, and milking machines will have an important impact in rural agricultural markets. In addition, there is a desire to produce electricity that can then run the same sorts of mechanical appliances. Finally, boilers and the ability to adapt existing productive thermal uses also has appeal to larger farmers to reduce costs and increase the services available on the farm. These products will be prioritized for release in selected markets in 2019 and scaled within the markets served by Sistema.bio.

Biogas chaff cutter

Biogas grain mill

Biogas water pump

Tortilla/ Chapati biogas stove

Biogas water heater

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